NOAA Technical Memorandum NWS ER-62

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

Gato
WES

LOCALLY HEAVY SNOW DOWNWIND FROM COOLING TOWERS

Reese E. Otts
WSFO Charleston, WV

Scientific Services Division
Eastern Region Headquarters
December 1976

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service

NOAA TECHNICAL MEMORANDA
National Weather Service, Eastern Region Subseries

The National Weather Service Eastern Region (ER) Subseries provides an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready for formal publications. The series is used to report on work in progress, to describe technical procedures and practices or to relate progress to a limited audience. These Technical Memoranda will report on investigations devoted primarily to regional and local problems of interest mainly to ER personnel, and hence will not be widely distributed.

Papers 1 to 22 are in the former series, ESSA Technical Memoranda, Eastern Region Technical Memoranda (ERTM); papers 23 to 37 are in the former series, ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM). Beginning with 38, the papers are now part of the series, NOAA Technical Memoranda NWS.

Papers 1 to 22 are available from the National Weather Service Eastern Region, Scientific Services Division, 585 Stewart Avenue, Garden City, N.Y. 11530. Beginning with 23, the papers are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. Prices vary for paper copy; $2.25 microfiche. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda

ERTM	1	Local Uses of Vorticity Prognoses in Weather Prediction. Carlos R. Dunn April 1965
ERTM	2	Application of the Barotropic Vorticity Prognostic Field to the Surface Forecast Problem. Silvio G. Simplicio. July 1965
ERTM	3	A Technique for Deriving an Objective Precipitation Forecast Scheme for Columbus, Ohio. Robert Kuessner. September 1965
ERTM	4	Stepwise Procedures for Developing Objective Aids for Forecasting the Probability of Precipitation. Carlos R. Dunn. November 1965
ERTM	5	A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. March 1966
ERTM	6	Evaluation of OFDEV Technical Note No. 17. Richard M. DeAngelis. March 1966
ERTM	7	Verification of Probability of Forecasts at Hartford, Connecticut, for the Period 1963-1965. Robert B. Wassall. March 1966
ERTM	8	Forest-Fire Pollution Episode in West Virginia November 8-12, 1964. Robert O. Weedfall. April 1966
ERTM	9	The Utilization of Radar in Meso-Scale Synoptic Analysis and Forecasting. Jerry D. Hill. March 1966
ERTM	10	Preliminary Evaluation of Probability of Precipitation Experiment. Carlos R. Dunn. May 1966
ERTM	11	Final Report. A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. May 1966
ERTM	12	Summary of Scientific Services Division Development Work in Sub-Synoptic Scale Analysis and Prediction - Fiscal Year 1966. Fred L. Zuckerberg.
ERTM	13	A Survey of the Role of Non-Adiabatic Heating and Cooling in Relation of the Development of Mid-Latitude Synoptic Systems. Constantine Zois. July 1966
ERTM	14	The Forecasting of Extratropical Onshore Gales at the Virginia Capes. Glen V. Sachse. August 1966
ERTM	15	Solar Radiation and Clover Temperatures. Alex J. Kish. September 1966
ERTM	16	The Effects of Dams, Reservoirs and Levees on River Forecasting. Richard M. Greening. September 1966
ERTM	17	Use of Reflectivity Measurements and Reflectivity Profiles for Determining Severe Storms. Robert E. Hamilton. October 1966
ERTM	18	Procedure for Developing a Nomograph for Use in Forecasting Phenological Events from Growing Degree Days. John C. Purvis and Milton Brown. December 1966
ERTM	19	Snowfall Statistics for Williamsport, Pa. Jack Hummel. January 1967
ERTM	20	Forecasting Maturity Date of Snap Beans in South Carolina. Alex J. Kish. March 1967
ERTM	21	New England Coastal Fog. Richard Fay. April 1967
ERTM	22	Rainfall Probability at Five Stations Near Pickens, South Carolina, 1957-1963. John C. Purvis. April 1967
WBTM ER	23	A Study of the Effect of Sea Surface Temperature on the Areal Distribution of Radar Detected Precipitation Over the South Carolina Coastal Waters. Edward Paquet. June 1967 (PB-180-612)
WBTM ER	24	An Example of Radar as a Tool in Forecasting Tidal Flooding. Edward P. Johnson. August 1967 (PB-180-613)
WBTM ER	25	Average Mixing Depths and Transport Wind Speeds over Eastern United States in 1965. Marvin E. Miller. August 1967 (PB-180-614)
WBTM ER	26	The Sleet Bright Band. Donald Marier. October 1967 (PB-180-615)
WBTM ER	27	A Study of Areas of Maximun Echo Tops in the Washington, D.C. Area During the Spring and Fall Months. Marie D. Fellechner. April 19 (PB-179-339)
WBTM ER	28	Washington Metopolitan Area Precipitation and Temperature Patterns. C.A. Woollum and N.L. Canfield. June 1968 (PB-179-340)
WBTM ER	29	Climatological Regime of Rainfall Associated with Hurricanes after Landfall. Robert W. Schoner. June 1968 (PB-179-341)
WBTM ER	30	Monthly Precipitation - Amount Probabilities for Selected Stations in Virginia. M.H. Bailey. June 1968 (PB-179-342)
WBTM ER	31	A Study of the Areal Distribution of Radar Detected Precipitation at Charleston, S.C. S.K. Parrish and M.A. Lopez. October 1968 (PB-180-480)
WBTM ER	32	The Meteorological and Hydrological Aspects of the May 1968 New Jersey Floods. Albert S. Kachic and William Long. February 1969 (Revised July 1970) (PB-194-222)
WBTM ER	33	A Climatology of Weather that Affects Prescribed Burning Operations at Columbia, South Carolina. S.E. Wasserman and J.D. Kanupp. December 1968 (COM-71-00194)
WBTM ER	34	A Review of Use of Radar in Detection of Tornadoes and Hail. R.E. Hamilton. December 1969 (PB-188-315)
WBTM ER	35	Objective Forecasts of Precipitation Using PE Model Output. Stanley E. Wasserman. July 1970 (PB-193-378)
WBTM ER	36	Summary of Radar Echoes in 1967 Near Buffalo, N.Y. Richard K. Sheffield. September 1970 (COM-71-00310)
WBTM ER	37	Objective Mesoscale Temperature Forecasts. Joseph P. Sobel. September 1970 (COM-71-0074)

NOAA Technical Memoranda NWS

NWS ER	38	Use of Primitive Equation Model Output to Forecast Winter Precipitation in the Northeast Coastal Sections of the United States. Stanley E. Wasserman and Harvey Rosenblum. December 1970 (COM-71-00138)
NWS ER	39	A Preliminary Climatology of Air Quality in Ohio. Marvin E. Miller. January 1971 (COM-71-00204)
NWS ER	40	Use of Detailed Radar Intensity Data in Mesoscale Surface Analysis. Robert E. Hamilton. March 1971 (COM-71-00573)
NWS ER	41	A Relationship Between Snow Accumulation and Snow Intensity as Determined from Visibility. Stanley E. Wasserman and Daniel J. Monte May 1971 (COM-71-00763)
NWS ER	42	A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971 (COM-71-00897)
NWS ER	43	Snow Squalls in the Lee of Lake Erie and Lake Ontario. Jerry D. Hill. August 1971 (COM-72-00959)
NWS ER	44	Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971 (COM-72-10332)
NWS ER	45	Forecasting Type of Precipitation. Stanley E. Wasserman. January 1972 (COM-72-10316)
NWS ER	46	An Objective Method of Forecasting Summertime Thunderstorms. John F. Townsend and Russell J. Younkin. May 1972 (COM-72-10765)
NWS ER	47	An Objective Method of Preparing Cloud Cover Forecasts. James R. Sims. August 1972 (COM-72-11382)
NWS ER	48	Accuracy of Automated Temperature Forecasts for Philadelphia as Related to Sky Condition and Wind Direction. Robert B. Wassall. September 1972 (COM-72-11473)
NWS ER	49	A Procedure for Improving National Meteorologiacal Center Objective Precipitation Forecasts. Joseph A. Ronco, Jr. November 1972 (COM-73-10132)
NWS ER	50	PEATMOS Probability of Precipitation Forecasts as an Aid in Predicting Precipitation Amounts. Stanley E. Wasserman. December 1972 (COM-73-10243)
NWS ER	51	Frequency and Intensity of Freezing Rain/Drizzle in Ohio. Marvin E. Miller. February 1973 (COM-73-10570)
NWS ER	52	Forecast and Warning Utilization of Radar Remote Facsimile Data. Robert E. Hamilton. July 1973 (COM-73-11275)
NWS ER	53	Summary of 1969 and 1970 Public Severe Thunderstorm and Tornado Watches Within the National Weather Service, Eastern Region. Marvin E. Miller and Lewis H. Ramey. October 1973 (COM-74-10160)
NWS ER	54	A Procedure for Improving National Meteorological Center Objective Precipitation Forecasts - Winter Season. Joseph A. Ronco, Jr. November 1973 (COM-74-10200)
NWS ER	55	Cause and Prediction of Beach Erosion. Stanley E. Wasserman and David B. Gilhousen. December 1973 (COM-74-10036)
NWS ER	56	Biometeorological Factors Affecting the Development and Spread of Plant Diseases. V. J. Valli. July 1974 (COM-74-11625/AS)
NWS ER	57	Heavy Fall and Winter Rain In The Carolina Mountains. David B. Gilhousen. October 1974 (COM-74-11761/AS)
NWS ER	58	An Analysis of Forecasters' Propensities In Maximum/Minimum Temperature Forecasts. I. Randy Racer. November 1974 (COM-75-10063/AS)

(Continued On Inside Rear Cover)

NOAA Technical Memorandum NWS ER-62

LOCALLY HEAVY SNOW DOWNWIND FROM COOLING TOWERS

Reese E. Otts
WSFO Charleston, WV

Scientific Services Division
Eastern Region Headquarters
December 1976

UNITED STATES
DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Weather
Service
George P. Cressman, Director

LOCALLY HEAVY SNOW DOWNWIND FROM COOLING TOWERS

Reese E. Otts
WSFO Charleston, West Virginia

1. INTRODUCTION

Previous studies have speculated about the environmental impact of cooling towers at power plants. Of particular concern has been the extent to which heat and moisture pollution may influence the behavior of the atmosphere. Hanna and Swisher (1971) concluded that the heat and moisture pollution from a power center could be of sufficient magnitude to affect the atmosphere significantly in the mesoscale.

2. OBSERVATIONS

Two locally heavy snowfalls were observed near Charleston, West Virginia in synoptic situations which experienced forecasters normally associate with light snowfall or snow flurry activity. In both cases, the heaviest snowfall occurred downwind from the John E. Amos Power Plant (2900 MWe), a complex that includes three of the largest cooling towers in the United States. The power plant is located about fifteen miles west northwest of Kanawha County Airport, the location of the National Weather Service observation site.

Informal visual observations in the first case led to speculation that the cooling towers may have contributed to the heavier snowfall. In the second case, observations by National Weather Service personnel and others provided stronger evidence that the cooling towers may have contributed to the heavy snowfall.

In the first case, on December 22, 1975, the Kanawha County West Virginia Sheriff's Communications Center reported one to two inches of snow in the South Charleston/St. Albans area at 4:00 A.M. EST, with heavy snow still in progress. No other locations in West Virginia were reporting heavy snow. The National Weather Service at Kanawha Airport, about four miles northeast of the area mentioned, reported only very small snowflakes with no accumulations. Consequently, the heavy snowfall was attributed to a local shower which was forecast to soon end.

However, by 7:00 A.M., the localized storm was continuing with accumulations estimated of three to five inches. Using all available data, the area of heavy snow was estimated to be about eight miles wide and twenty miles long (Figure 1.). The West Virginia Department of Highways reported the only road problems in the state were in that area. Documentation as to the actual extent was poor.

During this snowfall, cooling tower No. 2 at the Amos Plant, was not operative, tower No. 1 was operating at about 90% of full capacity, and tower No. 3 at about 80%. The average amount of water evaporated from the three towers at full capacity is 19,000 gallons per minute as described by Smith et al.

In the second case, the snow began about 7:00 A.M. EST, January 4, 1976. By 9:00 A.M., over two inches of snow had fallen on the ridge that runs parallel to the Kanawha River, just north of downtown Charleston. South of the river, there was no snowfall and the sun was visible most of the morning. Snow accumulation was over by 1:00 P.M.

Reliable snow depth measurements taken at 12:00 noon, January 4, 1976, were obtained from Office of Emergency Services volunteer weather observers. As their reports were plotted, a pattern emerged. Subsequently, calls were made to schools, rural post offices, service stations, and others who might have measured the snowfall. A well defined area was revealed (Figure 2.). Two inches or more occurred in about 100 square miles (two to four miles wide and twenty-five miles long). Within this area was a narrow band (one to two miles wide and twelve miles long) with depths of four to six inches. The National Weather Service at Kanawha Airport was in the band of heavier snow with four inches on the ground by noon. Although light showers did occur elsewhere in the state, no snowfall of more than one inch was reported over West Virginia that day. During this heavy snowfall, all three cooling towers at the Amos Power Plant operated at about two-thirds capacity until 8:00 A.M. and at full capacity after 8:00 A.M.

In the cases described, the snowfall occurred almost directly downwind from the Amos Power Plant. Winds aloft from Huntington, West Virginia upper air soundings indicated the average winds from 1,000 feet to 4,000 feet were compatible with the plume from the plant being blown over the heavier snowfall areas (Figures 1. and 2.).

In the first case, the winds were from the north northwest with the heavy snow occurring to the south southeast of the power plant. In the second case, the winds were from the west at the lowest levels veering to west northwest at 4,000 feet. The heavy snow occurred east southeast of the plant.

3. DISCUSSION

Evidence is presented which indicates that moisture and heat added to the atmosphere by large cooling towers may contribute significantly to heavy snowfalls in localized areas of West Virginia. Given favorable atmospheric conditions and proper geographical settings, mesoscale atmospheric phenomenons may be significantly influenced by the discharge from large cooling towers.

Close examination of the two cases presented here indicates that a low-level temperature inversion is a key meteorological factor (Figures 3, and 4.). Moist unstable air below the inversion was separated from dry, relatively stable air above. The input of heat and moisture from near the surface would have been trapped below the inversion and would have contributed to the precipitation processes in the lower layers of the atmosphere. With the occurrence of precipitation, latent heat released through the process of condensation could further contribute to instability and enhance the precipitation processes.

Both heavy snow events occurred in a penetrating cold air mass characterized by cyclonic curvature of the flow pattern. This most often occurs in the region during post cold-frontal situations following the northeast movement of a low-pressure center.

The average temperature of the layer from the ground to the bottom of the inversion was about minus 12°C, a temperature that is very favorable for nucleation and precipitation formation.

Geographical influences were likely involved. As the air moved toward the east and southeast over more rugged terrain, orographic lifting probably occurred. The importance of this effect cannot be determined here, but further observations of the effects of cooling towers in relatively flat terrain should verify or negate this proposal.

4. SUMMARY

Conditions favoring the development of locally heavy snows downwind from cooling towers appear to be as follows:

a. A strong influx of cold air into the area.

b. High relative humidity and an unstable lapse rate in the lower layers of the atmosphere.

c. A strong inversion layer near 5,000 feet (1,500 meters), topping the unstable lower layer.

d. Cyclonic curvature of the flow pattern.

e. An average temperature of minus 10°C or colder in the lower layer (from the ground to the bottom of the inversion).

f. Some initial orographic lifting or some other type of forced ascent to the airflow.

Strongest effects occur downwind from the source near the axis of the mean wind in the 1,000 - 4,000 foot layer.

5. CONCLUSIONS

Two heavy snowfalls near Charleston, West Virginia appear to have been induced by large cooling towers. In each case similar meteorological and geographical conditions prevailed. Mesoscale phenomena may be significantly influenced by large man-made sources of heat and moisture.

Forecasters suspecting such influences in their area should closely inspect the precipitation patterns when favorable conditions exist. Knowledge of these influences can provide the potential for "fine-tuning" the local weather forecasts.

ACKNOWLEDGMENTS

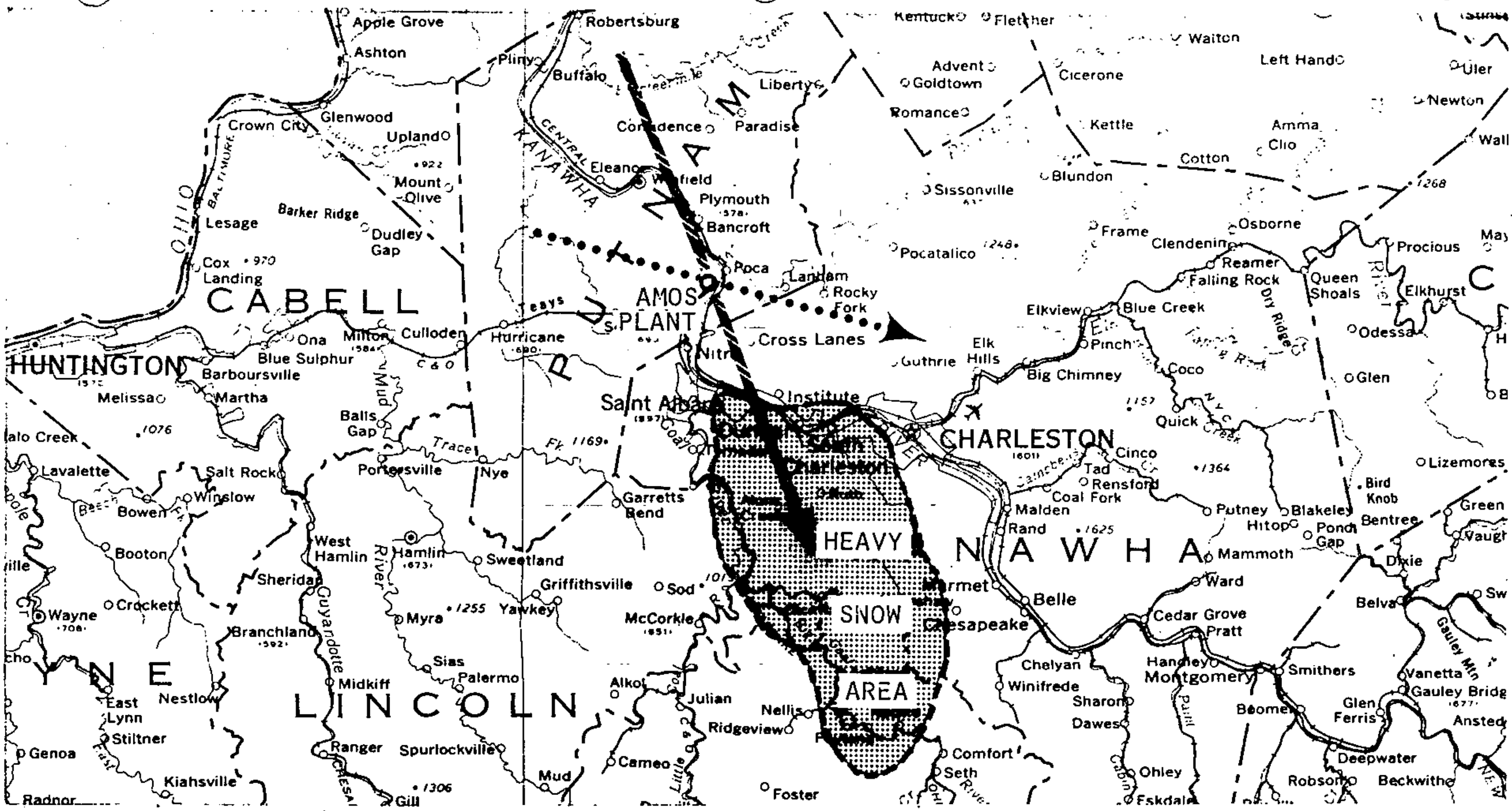
The author wishes to thank Messrs. Doyle Cook and R. F. Gonski for their helpful suggestions and assistance in reviewing this paper.

REFERENCES

Hanna, S. R. and S. D. Swisher: Meteorological Effects of the Heat and Moisture Produced by Man. Nuclear Safety, Vol. 12, No. 2, March-April 1971, pp. 118-119.

Kramer, M. L., et al.: Snowfall Observations from Natural-Draft Cooling Tower Plumes. Science, Vol. 193, September 24, 1976, pp. 1239-1241.

Smith, M. E., et al.: Cooling Towers and the Environment. American Electric Power Service Corp., New York, N. Y.



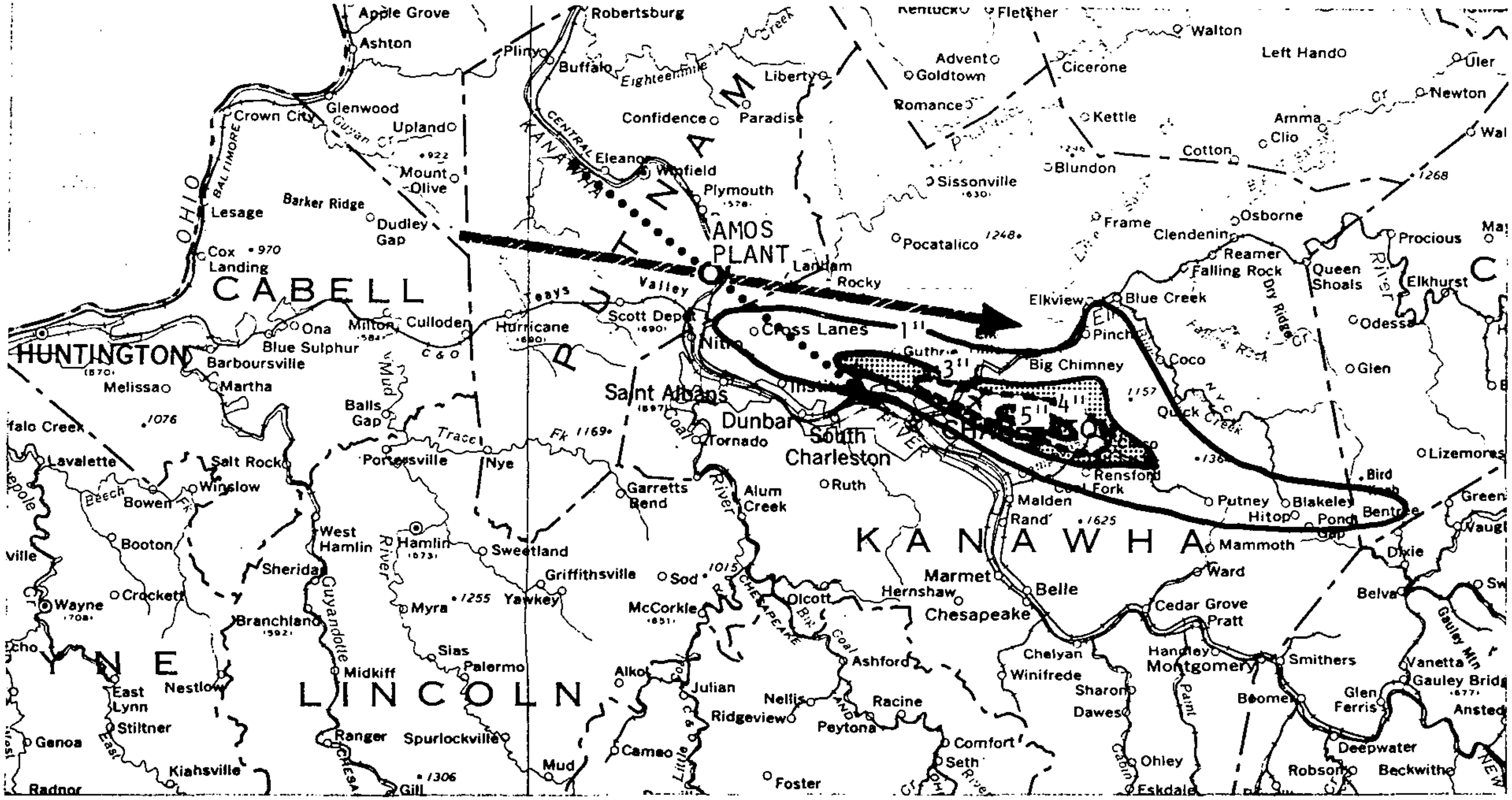
Mean Surface Wind Direction at Charleston, WV
5:00 AM - 9:00 AM EST

Mean Wind Direction 1000-4000 ft.
12Z (Huntington, WV)

10 0 10 20

SCALE: 1:500,000
One inch equals approximately 8 miles

Figure 1. Heavy Snow Area of December 22, 1975



Mean Surface Wind Direction at Charleston, WV
8:00 AM - 11:00 AM EST

Mean Wind Direction 1000-4000 ft.
12Z (Huntington, WV)

10 0 10 20 miles

SCALE: 1:500,000
One inch equals approximately 8 miles

Figure 2. Snow Depth Kanawha County, West Virginia
12 Noon January 4, 1976

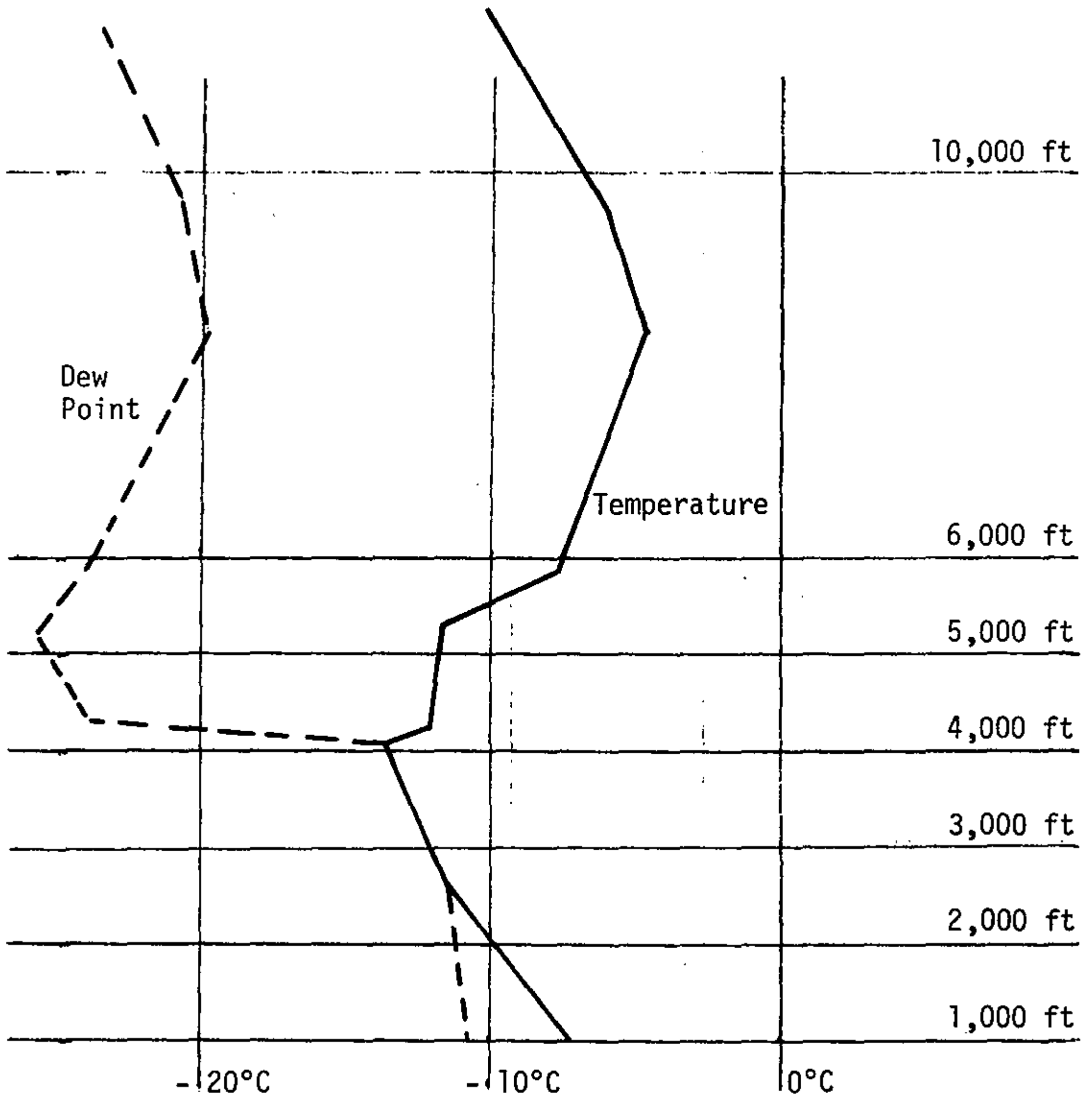


Figure 3. Upper Air Sounding - Huntington, West Virginia
1200Z (7:00 AM EST) December 22, 1975

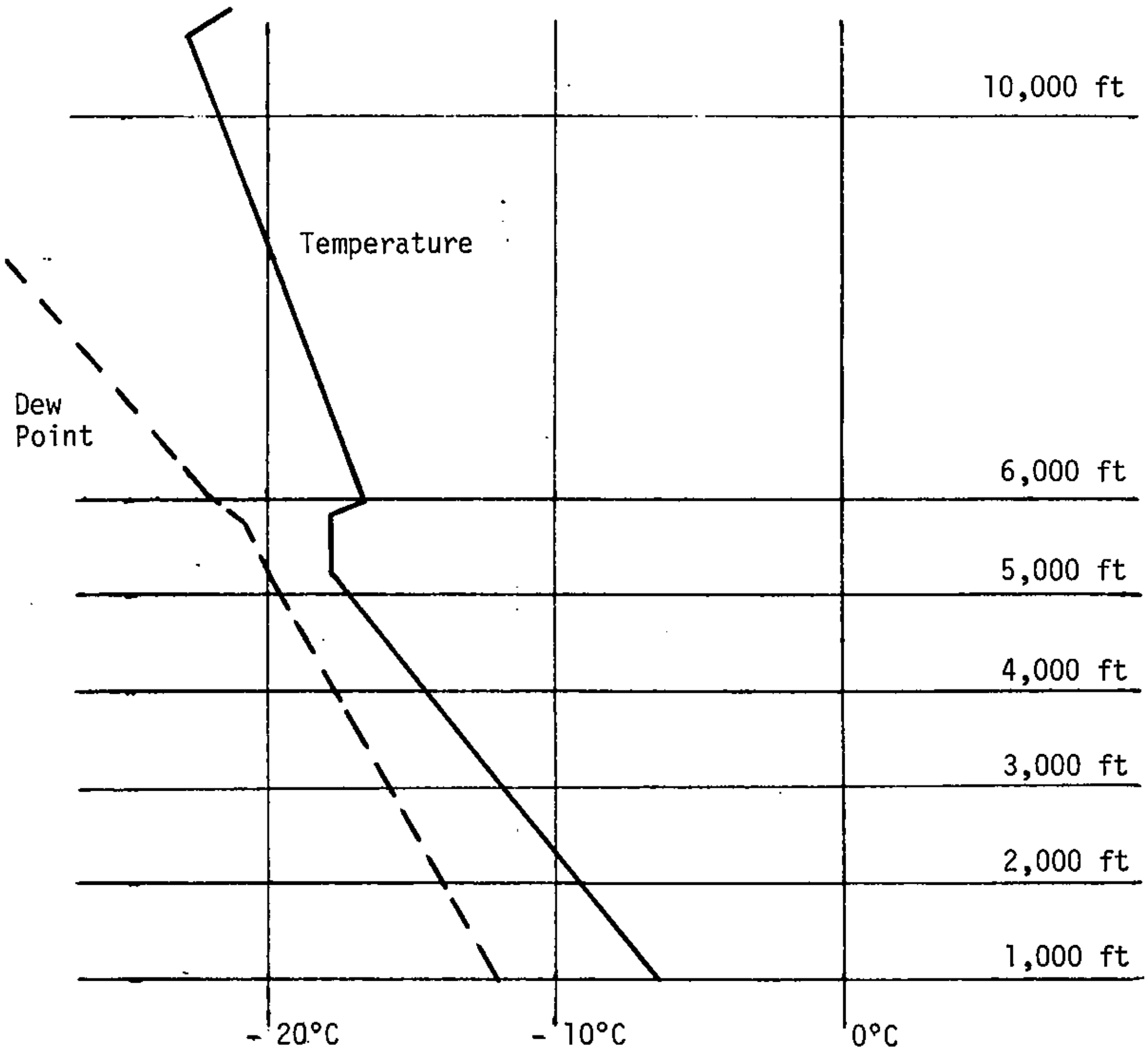


Figure 4. Upper Air Sounding - Huntington, West Virginia
1200Z (7:00 AM EST) January 4, 1976